

# ***Headquarters U.S. Air Force***

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## **UAS Operational Risk Management: How to Determine if a UAS is Safe Enough to Fly in the NAS**



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## ***Scope of This Presentation***

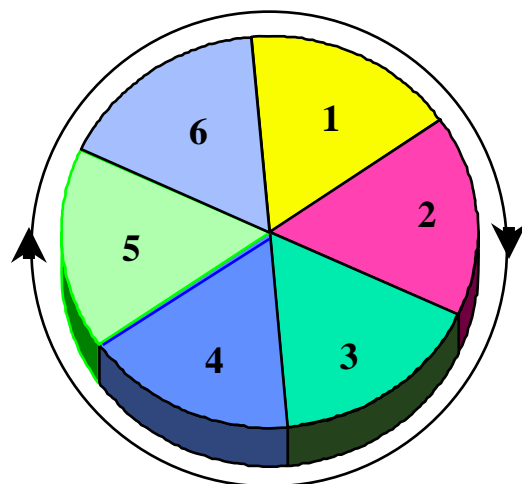
**This presentation:**

- 1) Identifies quantitative & qualitative methodologies used in assessing the operational risks for flying the Global Hawk in the National Airspace System (NAS) at Beale AFB, CA**
- 2) These methodologies are applicable to any UAS**
- 3) Is not the GH Operational Risk Management Assessment Report**



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# ***Operational Risk Management***



## **Operational Risk Management 6 Step Process**

**STEP 1 IDENTIFY THE HAZARD**

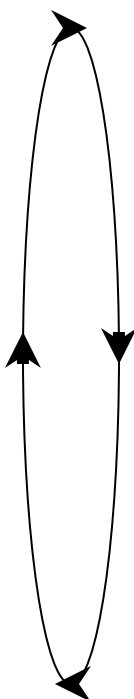
**STEP 2 ASSESS THE RISK**

**STEP 3 ANALYZE RISK CONTROL MEASURES**

**STEP 4 MAKE CONTROL DECISIONS**

**STEP 5 IMPLEMENT RISK CONTROLS**

**STEP 6 SUPERVISE AND REVIEW**



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## ***List of Sources Used***

- **Operational Risk Management – AFI 90-901&2**
- **Mil-Std-882D**
- **FAA System Safety Handbook**
- **AF Safety Center Safety Analysis Team (SAT) Process**
- **GH Safety Reports**
  - **Define GH/NAS Reported Hazards & Risk Control Measures**
- **GH Personnel at Beale**
  - **Define GH/NAS Unrevealed Hazards & Risk Control Measures**
- **Use of relevant existing mid-air collision research reports to help define the risk, e.g. NASA Studies, Academic Research etc.**



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## ***Context for Flying a UAS in NAS***

- **Why define the context for Flying in the NAS?**
  - **Knowing the context for flying a UAS in the NAS frames the scope of the assessment and helps identify hazards**
  - **FARs explain the context for flying in the NAS**
  - **Summarizing the FARs into required qualities of performance statements aid in identifying hazards**
  - **Required qualities of performance are not the hazards but are the lenses used by ORM assessors to see the hazards associated with a UAS flying in the NAS**



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## ***Required Qualities of Performance***

- **The following are the required qualities of performance for an aircraft (manned or unmanned) to safely fly in the NAS:**
  - **UAS able to fly Assigned, Vectored, Expected or Filed Routing & Altitudes**
  - **UAS able to fly Minimum Safe or Minimum Enroute Altitude**
  - **UAS see/detect and avoid traffic conflicts**
  - **UAS operator able to accomplish Air Traffic Control amendments**
  - **UAS able to be controlled by operator**

***(These aforementioned bullets are not mutually exclusive of each other and this list may be incomplete)***



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## *Identify The Hazard – Step 1*

- **Hazard:** Any real or potential condition that can cause injury, illness, or death to personnel; damage to or loss of a system, equipment, or property; or damage to the environment. (MIL-STD-882D, Document is Tab of FAA System Safety Handbook)
- **Hazard Statement:** Identifies an active hazard and the associated aircraft subsystem that precipitates the hazard
  - **Hazard Statement Syntax:** *(Active Hazard) due to (Underlying or Precipitating Deficiency)*
  - Hazard statement enables the ORM assessor to then determine the probability and severity of the undesired event(s)
  - All hazard statements must relate to the “Qualities of Performance for Flying in the NAS” to frame the scope of this ORM Assessment



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## *Identify The Hazard – Step 1*

- Determined ORM Assessment should address two undesirable outcomes:
  - A) Mid-Air Collision
  - B) Impact on Air Traffic Control
- Final Hazard Statement: *(Active Hazard) due to (Underlying or Precipitating Deficiency) that results in Mid-Air Collision or ATC Impact*
- Example Hazard Statements:
  - *Unintended altitude deviation due to lost data link that results in a mid-air collision or impact to ATC*
  - *Unable to see and avoid due to no sense and avoid capability that results in a mid-air collision or impact to ATC (in this case there is no subsystem)*
- 20 Hazards were Defined





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## ***Assess The Risk – Step 2***

- Risk is defined as the product of severity if an event were to take place and the probability of it occurring



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## Assess The Risk – Step 2

- **Assessing Severity requires tailored definitions for both undesirable outcomes (Mid-Air Collision & Impact to ATC)**

Description	Category	Severity Definition
Catastrophic	I	Could result in death, permanent total disability, loss exceeding \$1M, or irreversible severe environmental damage that violates law or regulation.  Results in loss of the system.
Critical	II	Could result in permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, loss exceeding \$200K but less than \$1M, or reversible environmental damage causing a violation of law or regulation.  Results in a large reduction in safety margin or functional capability. Also, results in a large increase in operator workload.
Marginal	III	Could result in injury or occupational illness resulting in one or more lost work day(s), loss exceeding \$20K but less than \$200K, or mitigatable environmental damage without violation of law or regulation where restoration activities can be accomplished.  Results in a significant reduction in safety margin or functional capability. Also, results in a significant increase in operator workload.
Negligible	IV	Could result in injury or illness not resulting in a lost work day, loss exceeding \$2K but less than \$20K, or minimal environmental damage not violating law or regulation.  Results in a slight reduction in safety margin or functional capability. Also, results in a slight increase in workload such as routine flight plan changes.

Tailored Severity Table (Mil Std 882D & FAA Systems Safety)



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## Assess The Risk – Step 2

TABLE A-II. Suggested mishap probability levels.

### ■ Probability has quantitative and qualitative definitions

Description*	Level	Specific Individual Item	Fleet or Inventory**
Frequent	A	Likely to occur often in the life of an item, with a probability of occurrence greater than $10^{-1}$ in that life.	Continuously experienced.
Probable	B	Will occur several times in the life of an item, with a probability of occurrence less than $10^{-1}$ but greater than $10^{-2}$ in that life.	Will occur frequently.
Occasional	C	Likely to occur some time in the life of an item, with a probability of occurrence less than $10^{-2}$ but greater than $10^{-3}$ in that life.	Will occur several times.
Remote	D	Unlikely but possible to occur in the life of an item, with a probability of occurrence less than $10^{-3}$ but greater than $10^{-6}$ in that life.	Unlikely, but can reasonably be expected to occur.
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced, with a probability of occurrence less than $10^{-6}$ in that life.	Unlikely to occur, but possible.



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## Assess The Risk – Step 2

Severity Category		Probability of Loss Level				
		FREQUENT $X > 10^{-1}$	PROBABLE $10^{-1} \geq X \geq 10^{-2}$	OCCASIONAL $10^{-2} \geq X \geq 10^{-3}$	REMOTE $10^{-3} \geq X \geq 10^{-6}$	IMPROBABLE $10^{-6} \geq X$
Catastrophic	I	HRI - 1 <b>IA</b>	HRI - 2 <b>IB</b>	HRI - 4 <b>IC</b>	HRI - 8 <b>ID</b>	HRI - 12 <b>IE</b>
Critical	II	HRI - 3 <b>IIA</b>	HRI - 5 <b>IIB</b>	HRI - 6 <b>IIC</b>	HRI - 10 <b>IID</b>	HRI - 15 <b>IIE</b>
Marginal	III	HRI - 7 <b>IIIA</b>	HRI - 9 <b>IIIB</b>	HRI - 11 <b>IIIC</b>	HRI - 14 <b>IIID</b>	HRI - 17 <b>IIIE</b>
Negligible	IV	HRI - 13 <b>IVA</b>	HRI - 16 <b>IVB</b>	HRI - 18 <b>IVC</b>	HRI - 19 <b>IVD</b>	HRI - 20 <b>IVE</b>
Unacceptable		Undesirable		Acceptable with Review		Acceptable

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## ***Assess The Risk – Step 2***

- **Assessment Team obtained consensus on scoring the risk for each hazard with respect to:**
  - A) Mid-Air Collision
  - B) Impact on Air Traffic Control
- ***Unable to see and avoid due to no sense and avoid capability that results in:***
  - A) Mid-Air Collision - ID
  - B) Impact to ATC - IIID

***(Note this involved ORM Assessment Team reviewing studies on UAS collision probabilities)***

- **20 Hazards were Scored – 8 Were Found with Excessive Risk**



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## Assess The Risk – Step 2

Severity Category		Probability of Loss Level				
		FREQUENT $X > 10^{-1}$	PROBABLE $10^{-1} \geq X \geq 10^{-2}$	OCCASIONAL $10^{-2} \geq X \geq 10^{-3}$	REMOTE $10^{-3} \geq X \geq 10^{-6}$	IMPROBABLE $10^{-6} \geq X$
A) Catastrophic	I	HRI - 1 IA	HRI - 2 IB	HRI - 4 IC	HRI - 8 ID	HRI - 12 IE
Critical	II	HRI - 3 IIA	HRI - 5 IIB	HRI - 6 IIC	HRI - 10 IID	HRI - 15 IIE
B) Marginal	III	HRI - 7 IIIA	HRI - 9 IIIB	HRI - 11 IIIC	HRI - 14 IIID	HRI - 17 IIIE
Negligible	IV	HRI - 13 IVA	HRI - 16 IVB	HRI - 18 IVC	HRI - 19 IVD	HRI - 20 IVE
		Unacceptable	Undesirable	Acceptable with Review	Acceptable	

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# ***Analyze Risk Control Measures – Step 3***

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- **Risk Control Mechanism**: An activity to reduce the risk of a hazard by preventing (lowering the probability of occurrence of the hazardous condition) and/or mitigating (decreasing the severity) the effects of an identified hazard
- **Assessment Team Defined Risk Control Mechanisms**
  - **Example**: “Isolate UAS from other aircraft with special use airspace with sufficient safe distance laterally and in altitude (TFR, altitude reservation, restricted airspace, etc.)”
- **47 Risk Controls were Defined**
  - **24 of 47 Risk Controls Identified to Address 8 Hazards with Excessive Risk**



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# ***Analyze Risk Control Measures – Step 3***

- **Effectiveness for 24 Controls was Assessed**
- **Effectiveness: How well a control mitigates or eliminates a specific hazard**
- **Criteria for this considers:**
  - **MIL-STD-882 Order of Precedence Identifies desired hierarchy**
    - Design Feature
    - Safety Feature or Device
    - Warning Device
    - Procedures or Training
  - **Risk Controls were scored for absolving or mitigating the Risk. Use Likert Scale to score each control mechanism for each Hazard it mitigates**

0 - No effect	3 - Quite effective
1 - Slightly effective	4 - Completely effective
2 - Moderately effective	





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# Analyze Risk Control Measures – Step 3

- Feasibility answers: Can I afford to implement a control
- Following 5 Factors were used to Score Feasibility for 24 Controls
  - Factor 1: Cost:
    - **Green** : Less Than \$100K
    - **Yellow**: Between \$100K and \$1M
    - **Red**: Greater Than \$1M
  - Factor 2: Time:
    - **Green**: Less Than 1 year
    - **Yellow**: Between 1 & 2 years
    - **Red**: Greater Than 2 years
  - Factor 3: Technology:
    - **Green**: Technology Exists & Control Readily Available
    - **Yellow**: Technology Available but Requires Translation to GH System
    - **Red**: Extensive Research & Technology Development Required
  - Factor 4: Organizational Impact:
    - **Green**: No Impact
    - **Yellow**: Reorganization required but no additional resources
    - **Red**: New organization & requires new resources
  - Factor 5: Mission Impact:
    - **Green**: No Impact
    - **Yellow**: Degraded Mission Capability
    - **Red**: Unable To Accomplish Required Mission

**Green** = 3  
**Yellow** = 2  
**Red** = 1



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## ***Analyze Risk Control Measures – Step 3***

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- **Assessment Team Individually Scored 24 Controls and then numerically Averaged:**
  - **Effectiveness – 24 Controls Scored with Respect to each of 8 Hazards**
  - **Feasibility – 5 Factors Lumped into 2 Categories**
    - **Programmatics: Cost, Time & Technology**
    - **Organizational: Organizational & Mission Impact**



## Make Control Decisions – Step 4

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- Select most Effective and most Feasible Controls
- Given Hazard 6:

Hazard ID	Hazard Statement	Assessed Risk - Mid-Air Collision	Assessed Risk - ATC Impact
H6	Traffic conflict with another aircraft while airborne due to no see and avoid capability	8 - ID	14 - IIID

- Control Effectiveness with Respect to Hazard 6:

Hazard	Control	Kowitz	Rutledge	Surowitz	Paxson	Average
H6	C18*	3	4	3	3	3.25
	C19	2	1	1	2	1.5
	C20	2	3	1	2	2
	C21	1	1	0	1	0.75
	C44	2	2	2	1	1.75
	C45	2	1	2	0	1.25
	C46*	4	3	3	3	3.25

**\* Same Effectiveness Value**



## Make Control Decisions – Step 4

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### ■ Control 46, Very Effective but Not Feasible:

Risk Control ID	Risk Control Statement	Hazard #
C46	Develop, Test & Install Aircraft Sense & Avoid Technology	H1, 6, 9, 10, 12, 14, 15, 17

Feasibility										
Control	Factors	Kowitz	Rutledge	Surowitz	Paxson	Ave	Prog	Org	Color	Key
C46	1	1	1	1	1	1	1	3		
	2	1	1	1	1	1				
	3	1	1	1	1	1				
	4	3	3	3	3	3				
	5	3	3	3	3	3				

Color	Key
	2.76 - 3
	2.26 - 2.75
	1.76 - 2.25
	1.26 - 1.75
	1 - 1.25



## Make Control Decisions – Step 4

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### ■ Control 18, Very Effective and Feasible:

Risk Control ID	Risk Control Statement	Hazard #
C18	Isolate GH from other aircraft with special use airspace with sufficient safe distance laterally and altitude (TFR, altitude reservation, restricted airspace, etc.)	H6, 9, 10, 14, 15, 17

Feasibility									Color	Key
Control	Factors	Kowitz	Rutledge	Surowitz	Paxson	Ave	Prog	Org		
C18	1	3	3	3	3	3	3	2.63		
	2	3	3	3	3	3				
	3	3	3	3	3	3				
	4	2	2	3	2	2.25				
	5	3	3	3	3	3				

### ■ 12 controls were finalized as recommendations



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## ***Residual Risk***

- **Residual Risk is the risk that is left over with controls in place**
- **When all of the Controls are implemented are you safe enough?**
  - **There is no official FAA policy established for probability of a mid-air collision; perhaps 1 collision in a billion flight hours**



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# Residual Risk

Severity Category		Probability of Loss Level					
		FREQUENT $X > 10^{-1}$	PROBABLE $10^{-1} \geq X \geq 10^{-2}$	OCCASIONAL $10^{-2} \geq X \geq 10^{-3}$	REMOTE $10^{-3} \geq X \geq 10^{-6}$	IMPROBABLE $10^{-6} \geq X \geq 10^{-9}$	EXTREMELY IMPROBABLE $10^{-9} \geq X$
Catastrophic	I	HRI - 1 IA	HRI - 2 IB	HRI - 4 IC	HRI - 8 ID	HRI - 10 IE	HRI - 20 IFX
Critical	II	HRI - 3 IIA	HRI - 5 IIB	HRI - 6 IIC	HRI - 10 IID	HRI - 15 IIE	HRI - 20 IIF
Marginal	III	HRI - 7 IIIA	HRI - 9 IIIB	HRI - 11 IIIC	HRI - 14 IIID	HRI - 15 IIIE	HRI - 20 IIF
Negligible	IV	HRI - 13 IVA	HRI - 16 IVB	HRI - 18 IVC	HRI - 19 IVD	HRI - 20 IVE	HRI - 20 IVF
		Unacceptable	Undesirable	Acceptable with Review		Acceptable	

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## ***Implement Risk Controls – Step 5***

- **ORM assessment provides an “informed decision” to Decision Makers**
- **Implementing Controls requires decision maker action**





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## ***Supervise and Review – Step 6***

- **Must ensure recommendation is properly implemented**
- **Steps 5 & 6 are more demanding as it entails participation by larger portion of responsible group**
- **Observe effectiveness of recommendation begin Step 1**



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# *Questions?*



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